DETECTION OF SMALL WATER-BODIES

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ABSTRACT

This paper provides information on how we have utilized two approaches for detection of small water bodies. The first approach requires use of an existing custom camera enclosure with three polarization filters at 0, 45, 90 degrees, intrinsically mounted, such that these filters and associated optics view exactly the same scene and so all three views are optically co-registered. The other approach requires use of three physically distinct cameras with the same type of polarization filters mounted on three low-cost off-the-shelf cameras each with similar optics, running with certain geometric approximations due to the flat-earth assumption. There are pros and cons for each approach. Results for an actual deployment are presented.

1.0 INTRODUCTION

The specific area addressed in this work is small water-body detection. Detection of such features is necessary for terrain classification and obstacle detection in natural environments. This work utilized data collection, experimental analysis and algorithm development steps to demonstrate the efficacy of these methods in a field experiment at Fort Indian Town Gap in May 2004. The hardware was integrated on the eXperimental Unmanned Vehicle (XUV) with help from General Dynamics Robotic Systems and these water detection methods were applied running on a vehicle in motion. The sensors can be seen mounted on the XUV in Fig. 5.

The purpose of this experiment was to evaluate the two approaches for water detection while respective sensor platform on the XUV vehicle is navigating the same terrain. The three camera sensor system is mounted just above the single camera system. These camera systems were integrated with the XUV interfaces and experimental work was done at Ft. Indian Town Gap. Results from these systems are presented here.

2.0. METHODS

A camera vision system usually focuses on reflected images on the water surface. The polarized light sensor detects the unique signature of the partially polarized light reflected off of the water for characterization. A ranging device such as a laser or LADAR usually returns a void for the region of the image with the water body due to the signal not getting reflected back to the sensor. We did not use the LADAR for this experiment but have demonstrated its utility in other related work.

The relative proportion of linear polarization is called partial polarization and the orientation of linear polarization is the phase. Together, intensity, partial polarization and phase completely determine the state of polarization. Partial linear polarization can be measured at a pixel level by

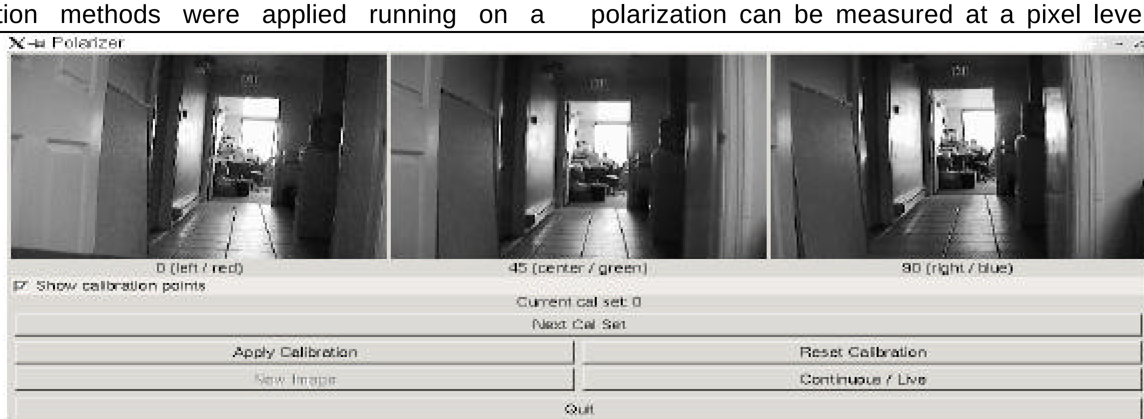

FIGURE 1: Image intensity calibration between the multiple polarization cameras. To correct for imaging in-homogeneities between the different cameras, a calibration process is used for equalization of imagery.

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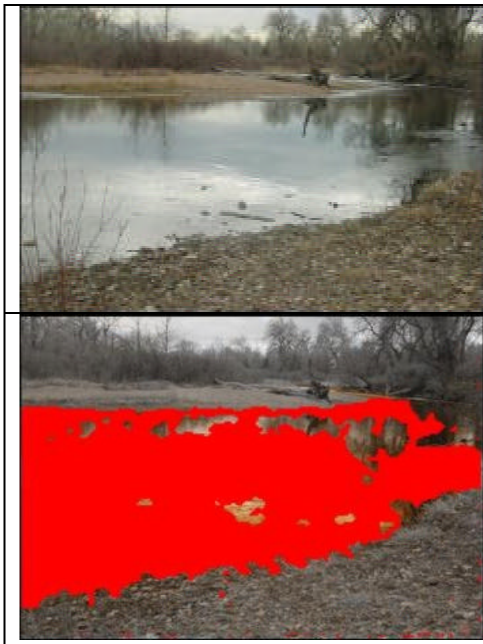

FIGURE 2: Water detection with static placement of camera and electronic control of the Polarization Filter angle settings.

the transmitted radiance through a polarization filter. The radiance varies *sinusoidally* with filter orientation. This approach is based on the previous work by Lawrence Wolff [1]

Two methods were utilized for detecting water puddles from a sensor platform in motion. The three camera method and the single camera with beam splitting method.

2.1. Three Camera Method

This approach acquires simultaneous images from three cameras such that each one is set at a particular polarization. The first camera has a polarization filter with polarization angle set at 0 degrees, the second is set at 45 degrees and the third is set at 90 degrees [1]. Each camera is positioned next to each other. The three cameras have a *firewire* interface and the user-interface (GUI) can display the three images at each sampling instant and accept user supplied training points, as shown in FIGURE 1. The training point selection allows the user to select corresponding points between the three views and then the images on the left and right of the center frame are warped to map and obtain corresponding pixels from all three views.

In cases where the platform is fixed, we can place the filter and electronically control the polarization angle to provide three views at 0, 45 and 90 degree polarization [2], with exactly the same optical path. Results for the situation with static placement of camera platform and the polarization filter being controlled electronically are shown in FIGURE. 2.

However vehicle platforms have to move and so the single camera approach will not work in these cases as it introduces delays between the acquisition of each polarization band resulting in artifacts and poor alignment between scene features. Three cameras were used so that there is no temporal delay between the captured images and all three views are acquired simultaneously. However, each polarization image will be geometrically misaligned from the others due to the finite distance between each camera [3]. When using multiple cameras, image quality differences due to camera setup and manufacturing variations become a factor and attention must be paid to equalization of the imagery produced by all three cameras.

For this application, we addressed this problem and developed a calibration technique for image equalization. A graphical user interface displays imagery from the three polarization cameras, and user will select corresponding calibration points in each image. Subsequently, the polarization module will utilize these calibration points to compute an equalization mapping between the cameras, which is used as a preprocessing step before polar data extraction. FIGURE 1, above, shows the calibration user interface. This approach assumed the flat-earth assumption to register the three cameras for water detection and this method will work well with features or water bodies on flat ground. The idea is to develop a mapping such that there is pixel based registration. A fourth camera, without any filter attached to it, can also be utilized for white-band normalization.

2.2. Single Camera System with Beam-Splitting

The second method utilized a camera system (Triscene) from Equinox Corp. This approach requires the incoming light to be split three ways such that 0, 45 and 90 degree polarization filter and internal lens observe the identical scene [1]. The main lens as shown mounted on the camera enclosure in FIGURE 3, and provides an optical path that is divided into three paths and each view

obtains image data that is registered with the other two.

FIGURE 3: Results from the Triscene camera used at Ft. Indian Town Gap. The left side shows the original raw image and the right side shows the segmented image with water labeled and shown in white.

This approach does not require a flat-world assumption for obtaining correspondence between views. However, it does require some fine tuning based on mechanical adjustment for rotation around its optical axis and also lateral adjustment for the two axes (horizontal and vertical). This mechanical adjustment helps provide for pixel and sub-pixel registration between views. This approach provided images that are inherently co-registered as all three lens and filter assemblies view the same scene by splitting the beam of light received by the main lens for images received at the three angles of polarization. The three cameras are shown in FIGURE 4, mounted in the side and back of the beam-splitter assembly.

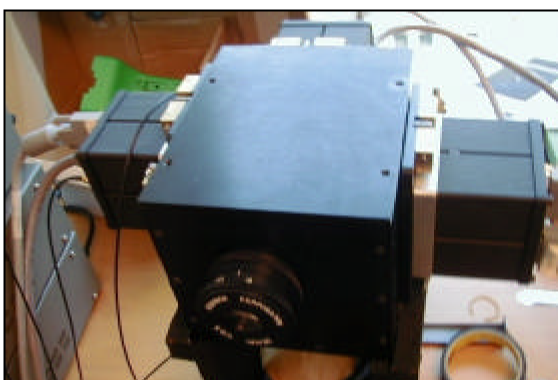

FIGURE 4: Triscene Camera used for the Water Detection Experiment

This assembly is shown mounted on the XUV for the demonstration at Fort Indian Town Gap in FIGURE 5. Off-the-shelf PMC type image acquisition cards from Bitflow Corp. were used for acquiring the three images. This hardware was installed on the Concurrent board, present in the XUV card cage, and connected to the cameras. The external (hardware) triggers to the cameras were provided by the serial port control available on the Concurrent board. Power was provided by a power supply with 115 V ac input from the vehicle inverter

FIGURES 3 and 5 shows raw images with the XUV in motion while traversing areas with water i.e. small lakes and water puddles, for the experiment. The classified image is shown to the right of FIGURE 3 and at the bottom right of FIGURE 5. These results show good correspondence with the raw image shown alongside. We were able to apply these methods in a repeatable manner for detecting “water - no-water” classification with satisfactory performance.

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CONCLUSION

We have seen application of the two methods for water detection. The benefits of the three camera approach is that it utilizes cameras, off-the-shelf, and the image acquisition is done using the three channels for data acquisition on the Concurrent board that exists on the XUV computer system. This method requires software GUI based calibration to provide co-registration of the three

views. One basic assumption that is made for this approach is that a flat-earth model is assumed and so it is likely that registration accuracy between views will decrease as the ground in the field of view of the cameras is not flat. The physically discrete cameras also have a tendency to have small variations in optics and image quality.

The single camera with beam splitting, has a custom enclosure and is a prototype camera system that is much more expensive compared to the system in the previous method. It does require some minor mechanical adjustment to obtain exact pixel resolution correspondence. It can also be mechanically tuned for sub-pixel correspondence between the three views. There is no need for warping the image between views by software methods as in the previous method. There is greater attenuation of light that is received in each internal lens with filter assembly. The results from both approaches were encouraging and each method has benefits that can be exploited for such deployments and field experiments.

FIGURE 5: Top Left: Triscene mounted on the XUV during set up and calibration. Top Middle: Triscene close-up, shown tilted down at 13 degrees. Top Right: XUV during the water-detection experiment at Indian Town Gap. Lower Left: Results are shown in real-time for operator visualization, during the experiment. Lower Middle: Scene for water detection, as seen by the cameras. Lower Right: Classification results of the water detection from this scene, with water shown in white.